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Section 1. Agriculture science

EFFECT OF AMMONIUM PHOSPHATE FERTILIZER ON ALFALFA (MEDICAGO SATIVA) PRODUCTIVITY IN UZBEKISTAN

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Abstract

The article provides results of scientific research on effect of ammonium phosphate fertilizer on productivity of alfalfa in the irrigated conditions of Uzbekistan. It is well known that the fertilization of alfalfa with ammonium phosphate is an important production factor to get high and stable yield in the country. It can be concluded that there is little known about alfalfa yield response to N rates and there is a need to further investigations on alfalfa yield response to N in the irrigated conditions of Uzbekistan.

Keywords: *Alfalfa, ammonium phosphate, fertilizer, irrigated conditions, plant height, and dry forage yield*

Introduction

Alfalfa (Medicago sativa) is an ancient forage crop in Central Asia. The crop is mainly cultivated in the irrigated conditions while in rainfed conditions mainly in mountain areas (350–1500 m above sea level) in Uzbekistan. Young stands of alfalfa usually produce the lowest yield in the first harvest year of alfalfa because the root system is not developed well and is not enough strong to produce long and thick stems. Traditionally alfalfa is not fertilized in the first harvest year in the irrigated conditions of Uzbekistan. A well planned fertilizer application management is necessary for improving forage production alfalfa. Newly seeded alfalfa needs a readily available supply of phosphorus, potassium and other plant nutrients immediately after emergence. In this regard, for the first time in the irrigated conditions of Uzbekistan alfalfa was fertilized in the first harvest year with ammonium phosphate in order to increase yield potential of the crop.

Soil and climatic conditions

This experiment was conducted at the six demonstrations farms of Bukhara district, Uzbekistan. Uzbekistan's soil is moderately eroded dark sierozems, middle loam (topsoil) and heavy loam (lower layers). Organic matter, content of carbonate and pH ranged

from 2.8 to 0.3%, 14.5 to 10.5%, and 7.5 to 8.7 respectively at the 0–5 and 80–100 cm deep profile. Soil – brown carbonate, heavy, large-dusty, medium-and heavily eroded. The humus content in the horizon 0–15 and 15–31 cm is 3.05 and 1.80% and total nitrogen is 0.18 and 0.12%. Phosphorus in the upper layer of the soil is 0.15–0.12%, but mobile forms of phosphorus are only 8.5–5.5 mg / kg of soil. The climate of Uzbekistan is classified as continental with hot summers and cold winters. The climate in the research Farm has a low humidity with hot summer and mild winter. The average summer temperatures is 30ºC often surpass 45 °C; the average winter temperature in January is about +1.9 °C, with absolute minimum as low as −30 °C. Uzbekistan experienced the worst winter in 44 years in 2008. Night temperatures ranged from −15 °C to −25 °C for extended periods in January and sometimes in February. The winter in 2007 and 2009 were as usual comparing to long term average temperatures. The winter of 2009 was favorable to the plant growth and development and warmer than usual and almost without snow while in 2008 were recorded heavy snowfalls especially in mountain areas.

Research method

The experiment was laid out in randomized complete block design. Plot size was 25 m² (10 × 2.5 m) and replication is fourfold. Total research area was 2400 m². The experiment was provided at six farmers' field. There were four treatments, fourth treatment (ammonium phosphate 80 kg ha −1) was added in the second experimental year, and these are as follows: control no fertilizer (AC) and three application rate of Ammonium phosphate at 40 (AC40), 60 (AC60) and 80 (AC80) kg ha – 1. First cut was done as of May 15 at the height of alfalfa 75–80 cm, in the beginning stage of flowering, and the cut was done manually at height of 5–7 cm from the ground. Field data for both experiments were collected on plant height, green forage yield and dry forage yield, and economics of fodder produced at market rates were recorded. Data analysis was performed using GenStat program.

Results

The results of this experiment showed that plant height is an important alfalfa trait when different ammonium phosphate application is used for. Analysis of variance in the table 1 shows that significant differences (< .001) between the farms, year and treatment were found in all measurements of first year alfalfa plant height while interaction was not found between treatment and farm (0.154), treatment and year (0.024). Also there was not significant interaction between treatment, farm and year where three factors' interaction was studied (0.984). The analyze show that alfalfa plant height responses to treatment, farm and year were significant (Table 1).

Table 1. *Analysis of variance*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	1890.00	630.00	49.15	<.001
Farm	5	5336.13	1067.23	83.27	<.001
Year	1	2230.20	2230.20	174.01	<.001
Treatment.Farm	15	270.37	18.02	1.41	0.154
Treatment.Year	2	98.73	49.37	3.85	0.024
Farm.Year	5	2614.30	522.86	40.80	<.001
Treatment.Farm.Year	10	36.22	3.62	0.28	0.984
Residual	126	1614.91	12.82		
Total	167	14090.85			

On the basis of our experiment it was found that the alfalfa crop grew the tallest plant height when the plant is fertilized with ammonium phosphate fertilization rate at 60 kg ha-1 (Figure 1). The highest plant height (88.7 cm) was recorded in 2019 with ammonium phosphate fertilizer rate 60 kg ha −1 in farm 1 while the lowest (52.6 cm) was recorded in 2020 with ammonium phosphate fertilization 80 kg ha −1 in farm 4. Ammonium phosphate fertilization rate at 80 kg ha −1 had shortest height even compare to control treat-

ment where no fertilization was applied. This shows that further increase of fertilizer rate negatively affects plant height of young stands of alfalfa plants in the first growing year.

Figure 1. *Alfalfa plant height as affected by different ammonium phosphate application rate, cm*
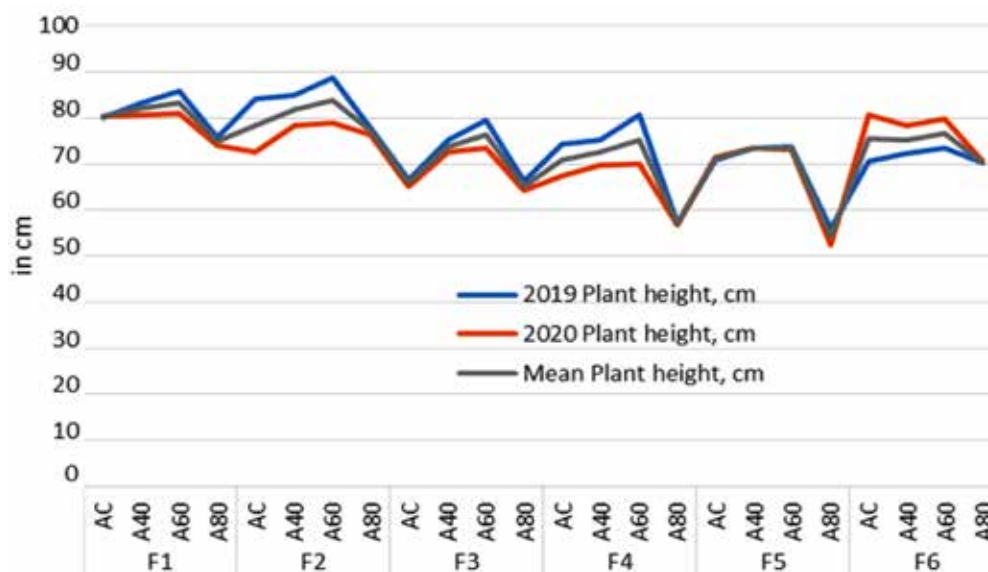
Alfalfa dry forage yield during the entire 2-yr period are reported in Table 2 along with analysis of variance. A significant (< .001) treatment by farm and farm by year interaction was found in dry forage yield. In addition individual treatments, farm and year experienced significant differences (<.001). There was not found any significant difference between treatment by year (0.153) and treatment by farm and year (0.529).

Table 2. *Analysis of variance*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
T	3	17.4169	5.8056	11.97	<.001
SITE	5	48.1782	9.6356	19.86	<.001
YEAR	1	10.7529	10.7529	22.16	<.001
T.SITE	15	21.4854	1.4324	2.95	<.001
T.YEAR	2	1.8487	0.9243	1.91	0.153
SITE.YEAR	5	57.8505	11.5701	23.85	<.001
T.SITE.YEAR	10	4.4012	0.4401	0.91	0.529
Residual	126	61.1356	0.4852		
Total	167	223.0693			

Dry forage yield was measured at all farms' alfalfa field during the performance of the experiment. Fertilizing alfalfa field with ammonium phosphate resulted in a yield increase each treatment compared to unfertilized alfalfa field. Significant differences among dry forage yield across the fertilization treatments were recorded and the highest yield was obtained when the ammonium phosphate rate was 40 kg ha −1 (Figure 2). It should be mentioned here that dry forage yield between 40 and 60 kg ha −1 ammonium phosphate application rates were not significantly differ. J. Caddel (2003) reports that phosphorus fertilizer can have a negative effect on alfalfa hay production in thinning stands if weeds are not controlled, especially if the phosphorus fertilizer contains nitrogen. In our experiment 80 kg ha −1 of ammonium phosphate fertilizer decreased dry forage yield of alfalfa. This shows that there is no need to further increase fertilizer rate which is negatively affect plant height, green and dry forage productivity of young stands of alfalfa plants in the first growing year.

Figure 2. *Alfalfa dry forage yield as influenced by different ammonium phosphate application rate*
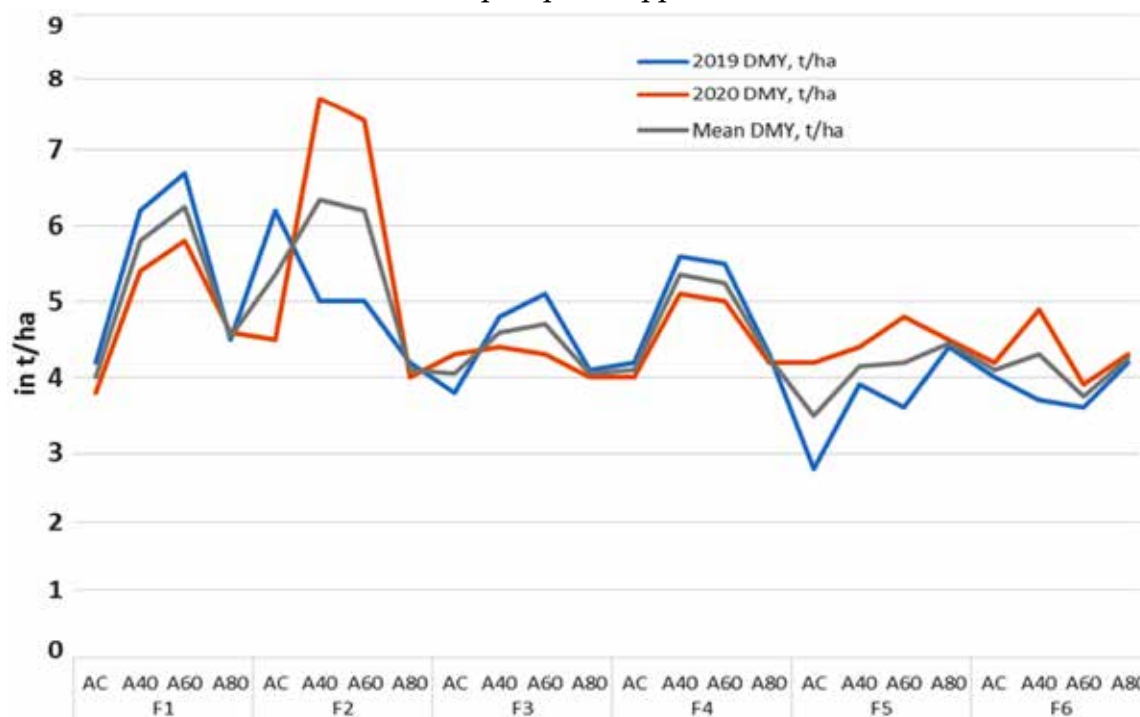
Little is known about alfalfa yield response to N rates. There is a need to further investigations on alfalfa yield response to N in the irrigated conditions of Uzbekistan.

Discussions and Conclusions

The analyze show that alfalfa plant height responses to treatment, farm and year were significant. On the basis of our experiment it was found that the alfalfa crop grew the tallest plant height when the plant is fertilized with ammonium phosphate fertilization rate at 40 kg ha −1. Ammonium phosphate fertilization rate at 80 kg ha −1 had shortest height even compare to control treatment where no fertilization was applied. Analysis of variance shows that alfalfa plant height responses to treatment, farm and year were significant.

A significant (< .001) treatment by farm and farm by year interaction was found in dry forage yield. Significant differences among dry forage yield across the fertilization treatments were recorded and the highest yield was obtained when the ammonium phosphate rate was 60 kg ha −1. Dry forage yield between 40 and 60 kg ha −1 ammonium phosphate application rates were not significantly differ. The fourth treatment (80 kg ha −1) of the experiment has decreased alfalfa plant height subsequently dry forage yield. This shows that there is no need to further increase fertilizer rate which is negatively affect plant height, green and dry forage productivity of young stands of alfalfa plants in the first growing year.

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Section 2. Chemistry

INFLUENCE OF MICELLAR STRUCTURES ON THE ADSORPTION CAPACITY OF SURFACTANTS

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Abstract

This paper continues the study of the adsorption properties of surfactants (surfactants) in aqueous solutions, with particular attention to the influence of micellar structures. The central theme of the study is to analyze the interaction between adsorption and micelle formation, and their influence on the technological properties of surfactants. The study details the thermodynamic and kinetic aspects of these processes, highlighting changes in Gibbs free energy and surface tension. Based on quantitative data, the paper demonstrates how the relationship between adsorption and micelle formation depends on the surfactant concentration in the solution. The results highlight the importance of an integrated approach to study surfactants and optimize their use in applications ranging from water purification to detergent development.

Keywords: *surfactants, adsorption, micelle formation, aqueous solutions, Gibbs free energy, surface tension, thermodynamics, kinetics*

Introduction

This article presents a continuation of our previous research cycle devoted to the study of adsorption properties of surfactants (surfactants) in aqueous solutions. Particular attention is given to analysing the influence of micellar structures on the adsorption efficiency of surfactants, which is a key factor in many technological and environmental processes. Our previous publications in this field (Maryaskin & Derman, 2019; Maryaskin & Derman, 2021) focused on basic aspects of adsorption and micelle formation, emphasising the importance of an integrated approach to the study of these phenomena.

We further extend this analysis by considering both thermodynamic and kinetic aspects of the interaction between adsorption

and micelle formation in the surfactant aqueous solution system. Building on previous work, we deepen our understanding of the mechanisms governing these processes and their influence on the technological properties of surfactants, including changes in Gibbs free energy and surface tension. The aim of this paper is to extend the theoretical framework, with the aim of optimising the use of surfactants in a variety of industries, from water treatment to the development of new detergents.

Adsorption of surfactants (surfactants), from aqueous media at various interfaces, is an important factor determining the efficiency of the technological properties of these solutions (ability to remove contaminants, emulsification, dispersion, etc.).

There are many theories devoted to the description of the adsorption process (Adamson, 1979; Hiemenz, & Rajagopala, 1997). However, these theories do not consider the fact that in aqueous solutions of surfactants, in addition to adsorption, the process of micelle formation can take place. In Maryaskin and Derman (2019) it is suggested that these simultaneous processes mutually influence each other. The present work is devoted to an attempt to consider such influence.

Consider a system consisting of an aqueous surfactant solution. Due to the specificity of its properties, some surfactants participate in the processes of adsorption and micelle formation, i.e., the initial number of individual surfactant particles in the solution volume decreases. Let us introduce the following notations:

τ — time to reach the equilibrium of adsorption and micelle formation processes.

c_0 — initial concentration of surfactant in the solution volume.

c — concentration of individual surfactants in the solution volume after adsorption and micelle formation.

During the time τ the concentration of individual surfactants in the solution volume decreased by $c_0 - c$:

$$\frac{dc}{d\tau} = c_0 - c \tag{1}$$

where $c_0 - c$ is the amount of surfactants adsorbed on the surface and grouped into micelles.

Let us denote by α the fraction, from $c_0 - c$, of surfactants adsorbed, and by β the fraction of surfactants that have formed micelles:

$$\frac{dc}{d\tau} = (c_0 - c)\alpha + (c_0 - c)\beta \tag{2}$$
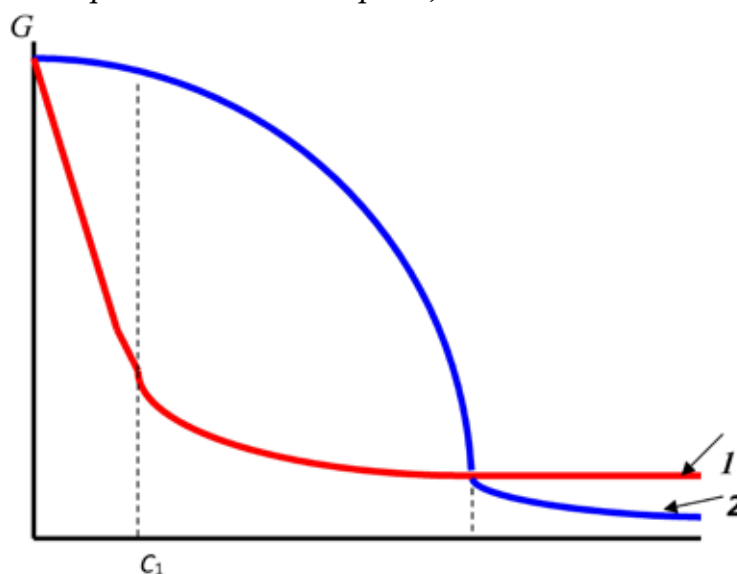
From (2), dividing the variables, we obtain:

$$\int_{c_0}^{c_0 - c} \frac{dc}{c_0 - c} = \alpha \int_0^{\tau} d\tau + \beta \int_0^{\tau} d\tau \tag{3}$$

Applying the substitution method, from (3) we obtain:

$$c = c_0 (1 - e^{-(\alpha + \beta)\tau}) \tag{4}$$

Figure 1. *Scheme of Gibbs free energy change in the processes: 1 − adsorption; 2 − micellization*

At low concentrations of surfactants in solution, surface-active particles easily reach the interface and adsorb on it. In this case $\alpha \gg \beta$ and the decrease in the amount of individual surfactants in the solution volume is mainly due to the adsorption process:

$$c = c_0(1 - e^{-\alpha\tau}) \qquad (5)$$

Accordingly, this spontaneous process is accompanied by a decrease in the Gibbs free energy (G). From Figure 1, this state of the system is maintained up to a surfactant concentration equal to C_1.

As the surfactant concentration increases in the solution volume, the probability of surface-active particles colliding with each other increases. In this case, it is difficult for surfactant particles to reach the interface surface and the probability of their adsorption decreases. At the same time, the probability of aggregation of surfactant particles into micelles increases. In this case, the decrease in the Gibbs free energy is due to the simultaneous occurrence of two processes: adsorption and micelle formation. From (Figure 1), such a state of the system takes place in the interval of surfactant concentrations between C_1 and C_k.

As is known, at the surfactant concentration in solution equal to the critical micelle formation concentration (C_k), intensive micelle formation is observed, and adsorption reaches its practically constant value. In this case, further decrease in the number of individual surface-active particles in the volume, is mainly due to their micelle formation and hence $\beta \gg \alpha$. Such a state corresponds to the section of (Figure 1), at concentrations higher than C_k.

Further, even though adsorption attributed to one mole of surfactant is energetically more favourable than micelle formation (Maryaskin & Derman, 2019), the second process, which involves many particles, occurs predominantly.

Let us consider the proposed scheme from the point of view of the laws of thermodynamics.

For an aqueous surfactant solution, the relationship between the isobaric-isothermal potential at adsorption and the chemical potential of the surface-active component, considering the interface area, is described by the equation (Hiemenz & Rajagopala, 1997):

$$G_{ads} = \sigma s + \mu_{ads} n_{ads} \qquad (6)$$

where G_{ads} – surface Gibbs free energy at adsorption, σ – surface tension of solution; s – surface area of interface; μ_{ads} – chemical potential of surface-active component at adsorption; n_{ads} – number of moles of adsorbed surface-active component.

As a result of adsorption there is a decrease in the surface tension at the interface between air and solution. This decrease continues up to the surfactant concentration in the solution, equal to the critical concentration of micelle formation (C_k), at which the surface tension reaches its minimum, constant in a certain range of concentrations, value (σ_{min}).

According to our assumption, this state can be influenced by the process of aggregation of surfactants into micelles, occurring in the solution volume.

According to Hill (2001), micellar structure can be considered as a system consisting of many nanoparticles distributed in a liquid medium. The thermodynamics of a system consisting of N identical spherical nanoparticles (micelles), with the average number of surfactant moles in each micelle equal to n_{mic}, was considered in Hill (1963) and Chamberlin (2015).

In the first approximation, the Gibbs energy of micelle formation is equal to:

$$G_{mic} = \mu_{mic} n_{mic} + NW \qquad (7)$$

where μ_{mic} – chemical potential of the surface-active component during micelle formation; W – value introduced for nanoparticles and characterized as the work of interfacial boundary formation (in this case, the micelle-solution interface).

As noted earlier, when C_k is reached, the free energies of adsorption and micelle formation processes are equal to each other. In this case, from (6), (7) we obtain, taking the interface area as a unit:

$$\sigma_{min} = \mu_{mic} n_{mic} - \mu_{ads} n_{ads} + NW \qquad (8)$$

From (8) it can be seen that the value σ_{min} achieved in aqueous solutions with surfactant concentration equal to C_k is the resultant of two processes: adsorption and micelle formation. This value remains almost constant with some increase in surfactant concentration. According to (8), it is possible at insignificant change of all parameters of the system. However, further increase in surfactant concentration often leads to the destruction of micellar

structures, which is again accompanied by a decrease in surface tension.

Using the data given in Maryaskin and Derman (2019) on the change of Gibbs free energy during adsorption of one mole of surfactant (ΔG^0_{ads}) attributed to the surface unit, the change of this energy for surfactant in the amount equal to A∞ was calculated:

$$\Delta G_{ads} = \Delta G^0_{ads} \times A_\infty \qquad (9)$$

where A_∞ is the limiting adsorption achieved at the critical concentration of micelle formation, ΔG_{ads} is the change in Gibbs energy during adsorption of surfactant in an amount equal to A_∞.

Further, using the data on the Gibbs free energy change during micelle formation of one mole of surfactant (ΔG^0_{mic}) (Maryaskin & Derman, 2019), and the assumption that at Ck the equality between the reduction of free energies of adsorption and micelle formation processes is reached, the number of surfactant moles participating in micelle formation Σn_{mic} was calculated:

$$\sum n_{mic} = \Delta G_{ads} \div \Delta G^0_{mic} \qquad (10)$$

The value of Σn_{mic} per unit volume of solution is equal to the concentration of surfactants forming micelles, C_{mic} (mol/m³).

The total concentration of surfactants adsorbed and formed micelles (C_{tot}) is:

$$C_{tot} = A_\infty + C_{mic} \qquad (11)$$

The results of the calculations are given in Tables 1, 2. It follows from these data that the amount of surfactants grouped into micelles in all cases is greater than that adsorbed on the surface. Also note that in the processes of adsorption and micelle formation participate only a small part of the total amount of surface-active particles ($C_{tot} \ll C_k$). However, it should be considered that in technological processes, as a rule, solutions with surfactant concentration several times higher than the critical concentration of micelle formation are used. In this case, the value of C_{tot} will be larger than shown in the tables.

Table 1. *Amounts of adsorbed and micelle-forming molecular surfactants (T = 288 K)*

Substance formula	$\Delta G^0_{ads}*10^{-3}$, J/mol *	$\Delta G^0_{mic}*10^{-3}$, J/mol *	C_k, mol/m³ *	D	$A_\infty*10^6$, mol/m²	$C_{mic}*10^6$, mol/m³	$C_{tot}*10^6$, mol/м³
$C_8H_{17}O(C_2H_4O)_3H$	−35.90	−21.10	8.214	−0.075	2.09	3.55	5.64
$C_{10}H_{21}O(C_2H_4O)_3H$	−43.87	−26.84	0.744	−0.110	2.51	4.10	6.61
$C_{12}H_{25}O(C_2H_4O)_3H$	−45.47	−34.46	0.031	−0.171	3.76	4.96	8.72
$C_8H_{17}O(C_2H_4O)_6H$	−40.09	−20.10	12.59	−0.067	1.67	3.33	5.0
$C_{10}H_{21}O(C_2H_4O)_6H$	−43.56	−25.41	1.36	−0.091	2.09	3.58	5.67
$C_{12}H_{25}O(C_2H_4O)_6H$	−47.86	−32.06	0.084	−0.120	2.51	3.75	6.26
$C_8H_{17}O(C_2H_4O)_8H$	−35.30	−18.93	20.40	−0.059	1.67	3.11	4.78
$C_{12}H_{25}O(C_2H_4O)_8H$	−49.30	−31.41	0.11	−0.103	2.09	3.28	5.37
$C_{14}H_{29}O(C_2H_4O)_8H$	−49.95	−37.49	0.0087	−0.167	3.34	4.45	7.79
C8H17O(C2H4O)10H	−44.68	−17.63	35.74	−0.056	1.25	3.16	4.41
$C_{10}H_{21}O(C_2H_4O)_{10}H$	−50.26	−25.17	1.49	−0.063	1.25	2.49	3.74
$C_{12}H_{25}O(C_2H_4O)_{10}H$	−44.99	−30.62	0.12	−0.094	2.09	3.07	5.16
$C_{14}H_{29}O(C_2H_4O)_{10}H$	−58.87	−37.14	0.01	−0.123	2.09	3.31	5.40
$C_8H_{17}O(C_2H_4O)_{12}H$	−42.29	−17.51	37.74	−0.053	1.25	3.02	4.27
$C_{10}H_{21}O(C_2H_4O)_{12}H$	−41.88	−24.87	1.69	−0.070	1.67	2.81	4.48
$C_{12}H_{25}O(C_2H_4O)_{12}H$	−44.51	−29.19	0.144	−0.093	2.09	3.19	5.28
$C_{14}H_{29}O(C_2H_4O)_{12}H$	−50.26	−37.03	0.01	−0.126	2.51	3.41	5.92
$C_8H_{17}O(C_2H_4O)_{14}H$	−39.01	−17.30	41.35	−0.049	1.25	2.82	4.07
$C_{12}H_{25}O(C_2H_4O)_{14}H$	−51.45	−29.47	0.25	−0.086	1.67	2.91	4.58
$C_{14}H_{29}O(C_2H_4O)_{14}H$	−52.17	−36.73	0.012	−0.109	2.09	2.97	5.06

* *Maryaskin & Derman (2019)*

Table 2. *Amounts of adsorbed and micelle-forming molecular surfactants (T = 298 K)*

Substance formula	ΔG^0_{ads} *10⁻³. J/mol *	ΔG^0_{mic} *10⁻³. J/mol *	C_k. mol/m³ *	D	A_∞ *10⁶. mol/m²	C_{mic} *10⁶. mol/m³	C_{tot} *10⁶. mol/m³
$C_8H_{17}O(C_2H_4O)_3H$	−41.08	−24.57	5.52	−0.0797	1.94	3.24	5.18
$C_{10}H_{21}O(C_2H_4O)_3H$	−44.23	−28.77	0.49	−0.118	2.66	4.10	6.76
$C_{12}H_{25}O(C_2H_4O)_3H$	−50.58	−37.41	0.015	−0.159	3.15	4.25	7.40
$C_8H_{17}O(C_2H_4O)_6H$	−40.23	−22.08	7.48	−0.070	1.74	3.17	4.91
$C_{10}H_{21}O(C_2H_4O)_6H$	−43.69	−27.52	0.83	−0.093	2.14	3.40	5.54
$C_{12}H_{25}O(C_2H_4O)_6H$	−49.48	−36.32	0.24	−0.140	2.83	3.85	6.68
$C_8H_{17}O(C_2H_4O)_8H$	−38.00	−20.61	13.49	−0.061	1.61	2.96	4.57
$C_{12}H_{25}O(C_2H_4O)_8H$	−50.25	−34.24	0.055	−0.109	2.18	3.18	5.36
$C_{14}H_{29}O(C_2H_4O)_8H$	−54.92	−41.77	0.026	−0.158	2.87	3.78	6.65
$C_8H_{17}O(C_2H_4O)_{10}H$	−42.23	−20.56	13.76	−0.054	1.29	2.63	3.92
$C_{10}H_{21}O(C_2H_4O)_{10}H$	−43.98	−27.52	0.83	−0.080	1.82	2.91	4.73
$C_{12}H_{25}O(C_2H_4O)_{10}H$	−48.82	−30.60	0.063	−0.089	1.82	2.91	4.73
$C_{14}H_{29}O(C_2H_4O)_{10}H$	−57.59	−41.40	0.003	−0.131	2.26	3.16	5.42
$C_8H_{17}O(C_2H_4O)_{12}H$	−39.11	−19.44	21.59	−0.0536	1.37	2.76	4.13
$C_{10}H_{21}O(C_2H_4O)_{12}H$	−44.74	−27.80	0.74	−0.076	1.70	2.73	4.43
$C_{12}H_{25}O(C_2H_4O)_{12}H$	−50.61	−33.51	0.074	−0.096	1.90	2.86	4.76
$C_{14}H_{29}O(C_2H_4O)_{12}H$	−54.43	−40.04	0.0053	−0.134	2.46	3.32	5.78
$C_8H_{17}O(C_2H_4O)_{14}H$	−40.36	−18.56	30.86	−0.049	1.21	2.64	3.85
$C_{12}H_{25}O(C_2H_4O)_{14}H$	−49.54	−32.48	0.11	−0.090	1.82	2.77	4.59
$C_{14}H_{29}O(C_2H_4O)_{14}H$	−54.34	−39.44	0.0072	−0.125	2.30	3.17	5.47

* *Maryaskin & Derman (2019)*

As noted, the use of surfactants in technological processes is associated with their adsorption activity at the corresponding interfaces. It can be assumed that the presence of many micelles in the volume will affect the technological properties of surfactant solutions, for example, the rate of delivery of surface-active particles to the treated surfaces.

This, in particular, is shown in Maryaskin and Derman (2021), on the example of the use in the washing process of two molecular surfactants with approximately the same adsorption characteristics. Nevertheless, the cleaning rate in these micellar solutions differs significantly, which may be related to the above-mentioned kinetic factor.

All of the above reveals a complex relationship between adsorption and micelle formation. The paper emphasizes that in aqueous surfactant solutions these two processes not only occur in parallel but also mutually influence each other, which is important for understanding their technological characteristics.

The key point is the finding that at low surfactant concentrations adsorption dominates, while with increasing concentration there is a transition to the predominance of micelle formation. This accounts for changes in the Gibbs free energy and surface tension of the solution. Especially significant is the establishment of the critical concentration of micelle formation (C_k), at which the minimum of surface tension is reached.

The results of the study show that adsorption and micelle formation are complementary processes, and their ratio depends on the initial concentration of surfactant in the solution. It is also observed that only a fraction of surfactant particles is involved in the adsorption and micelle formation processes.

This has important practical implications for the application of surfactants in various technological processes such as cleaning, emulsification, and dispersion. Understanding the mechanisms of interaction between adsorption and micelle formation can facilitate

the development of more efficient and targeted surfactant applications in industry.

The authors plan to further discuss this topic in their next publication.

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Section 3. Economic and managment

METHODOLOGY FOR ASSESSING OF TAX COLLECTION: FROM TRADITIONAL TO TECHNOLOGY-BASED APPROACHES

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Abstract

This article provides a comprehensive analysis of the methodologies used for assessing tax collection, with a focus on the evolution from traditional to modern, technology-based approaches. Through a detailed examination of various methods, including the integration of artificial intelligence, blockchain, and data analytics, the study highlights the increasing efficiency and compliance rates associated with modern methodologies.

Keywords: *tax collection methodologies, modern taxation systems, artificial intelligence in taxation, blockchain in tax administration, comparative tax system analysis, tax compliance and efficiency, fiscal policy and administration*

Introduction

In the intricate world of fiscal policy and government finance, the assessment of tax collection efficiency stands as a pivotal component. This article delves into the methodologies employed to evaluate the level of tax collection, a critical factor influencing national economic health and governance. Taxation, being the primary source of government revenue, necessitates a robust and transparent assessment mechanism to ensure efficacy and compliance.

Our exploration begins with a historical perspective, tracing the evolution of tax collection methods and their impact on economic systems. We then introduce the key indicators and metrics used in modern tax assessment, discussing their roles in providing a comprehensive understanding of tax system performance.

Furthermore, this article examines the challenges faced in tax collection assessment, including data availability, the complexity of tax codes, and the impact of economic and social factors. We also consider the role of technology in enhancing tax collection and assessment methods, highlighting innovations that have revolutionized this field.

The methodology discussed herein is not just a theoretical framework but also a practical guide. It includes case studies and real-world examples, offering insights into the

application of these methods across different jurisdictions and tax systems.

Ultimately, this article aims to provide policymakers, economists, and fiscal analysts with a deeper understanding of how to effectively assess tax collection levels, ensuring that this crucial aspect of public finance is managed with the utmost efficiency and integrity.

Literature review

Smith's seminal work offers foundational insights into early tax theories, which set the stage for modern tax assessment methodologies (Smith, A., 1776).

Jones, L. & Silver, R.'s article provides a detailed historical overview of tax collection systems and their evolution over centuries, highlighting the transition from traditional to contemporary methods (Jones, L., & Silver, R., 1995). Greenwood's study focuses on the strategies employed in modern tax systems, evaluating their success rates in various economies (Greenwood, P., 2010). Chen's paper offers a comparative study, highlighting the differences in tax assessment methods between developing and developed countries and their effectiveness (Chen, Y., 2018). "AI and Tax Collection: The Future is Now" by Miller, T. & Jackson, B. explores the integration of artificial intelligence in tax collection, assessing its impact on efficiency and compliance (Miller, T., & Jackson, B., 2020). Santos investigates the potential of blockchain technology in revolutionizing tax collection and assessment (Santos, A., 2022). Adams' research discusses the unique challenges faced in tax collection in emerging economies, such as inadequate data and complex tax evasion schemes (Adams, R., 2015). White, S. & Kumar, N.'s article "Limitations of Current Tax Assessment Models" critically examines the limitations of current tax assessment models, suggesting areas for improvement and future research.

Table 1. *Evolution of Tax Assessment Methods*

Time Period	Methodology	Key Features	Regions Used
Pre-20th Century	Manual Ledger	Paper-based, manual recording	Global, varied by region
Early 20th Century	Basic Computational Tools	Use of calculators and basic computing	Developed countries
Late 20th Century	Computerized Systems	Digital recording, basic databases	Globally, with a focus in developed countries
21st Century	AI & Blockchain	Automated compliance checks, fraud detection, blockchain for transparency	Emerging globally

This table traces the historical evolution of tax assessment methods, highlighting the transition from manual, paper-based systems to modern, technology-driven approaches. There's a clear progression from manual to automated systems, reflecting advancements in technology and the increasing complexity of tax systems. The adoption of advanced methodologies is not uniform globally, indicating differences in technological infrastructure and administrative capabilities across regions.

Results

To analyze the comparison between traditional and modern tax collection methods, we can focus on various aspects such as their efficiency, compliance rates, technological integration, and applicability across different economies. Let's break down these aspects

Table 2. *Comparison of Traditional vs. Modern Tax Collection Methods*

Methodology	Compliance Rate	Efficiency	Technological Integration	Applicability
Traditional	Low-Medium	Low	Minimal	Mostly in developing countries
Modern	High	High	Extensive (AI, ML, Big Data)	Globally, with emphasis in developed countries

Traditional Methods:
- Typically characterized by manual processes, paper-based record-keeping, and face-to-face interactions.
- Efficiency is often limited due to the time-consuming nature of manual tasks, human error, and slower processing of data and payments.

Modern Methods:
- Utilize advanced technologies like AI, data analytics, and electronic payment systems.
- Significantly more efficient, with faster processing times, reduced errors, and the ability to handle large volumes of transactions and data.

AI algorithms are capable of analyzing complex tax data sets, detecting patterns, and identifying discrepancies or anomalies that could indicate non-compliance or fraud. AI can enhance the accuracy and thoroughness of audits, making them more targeted and effective. AI significantly reduces the manual workload in tax administration by automating repetitive tasks like data entry, classification, and basic analysis. Advanced AI systems can also provide predictive insights, aiding in policy-making and risk assessment, thereby making the administrative process more proactive rather than reactive.

Blockchain's strength lies in creating a transparent and tamper-evident record system. This can deter fraudulent activities and enhance compliance through increased accountability. However, its effectiveness is contingent on the integration of blockchain systems with existing tax infrastructure and taxpayer participation. Blockchain can streamline certain processes such as transaction verification and record-keeping. It ensures data integrity, which is crucial for tax records.

Data analytics allows for the thorough examination of vast amounts of tax data, enabling the identification of trends, outliers, and potential areas of non-compliance. It can be used for risk assessment, helping to prioritize resources towards higher-risk cases or areas with higher non-compliance rates. By leveraging data analytics, tax administrations can make more informed decisions, optimize resource allocation, and tailor their strategies to be more effective and efficient.

The combination of AI, Blockchain, and Data Analytics has the potential to transform tax administration significantly. While each tool has its strengths, their integration could lead to a more robust, efficient, and transparent tax system. The deployment of these technologies comes with challenges, including the need for substantial investment, training of personnel, ensuring data privacy, and integrating new systems with existing infrastructure. The ongoing development in these technologies suggests a future where tax administration becomes more proactive, data-driven, and user-friendly, ultimately leading to better compliance and more efficient operations.

Table 3. *Effectiveness of Different Tax Collection Tools*

Tool	Description	Impact on Compliance	Impact on Administration Efficiency
AI	Automated data analysis and prediction	High	High
Blockchain	Decentralized ledger for transparency	Medium	Medium
Data Analytics	Analysis of large tax data sets	High	High

This analysis highlights that while AI and Data Analytics have a more direct and pronounced impact on compliance and efficiency, Blockchain serves as a supportive technology enhancing transparency and data integrity. The successful implementation of these technologies in tax administration requires a holistic approach, addressing both technical and organizational challenges.

Implementing modern tax collection methodologies, while beneficial in enhancing efficiency and compliance, comes with its

METHODOLOGY FOR ASSESSING OF TAX COLLECTION: FROM TRADITIONAL

own set of challenges. These challenges can be broadly categorized into technical, financial, organizational, and societal aspects. Modern systems often require integrating new technologies with existing legacy systems, which can be complex and technically challenging. With the increased use of digital data, ensuring its security and protecting taxpayer privacy becomes paramount. This involves safeguarding against cyber threats and data breaches.

Technology evolves rapidly, and tax authorities need to continuously update their systems and tools to stay current, which can be a technically demanding task. Implementing modern tax systems often requires significant upfront investment in technology, infrastructure, and training. Particularly in developing countries, budget constraints can limit the ability to invest in the necessary technology and infrastructure. Ongoing maintenance and periodic upgrades of the systems add to the financial burden. Taxpayers also need to adapt to new ways of interacting with tax authorities, such as using digital platforms for filing and payments. In regions with limited access to technology or where digital literacy is low, modernizing tax collection can widen the gap between different segments of society. Gaining public trust in new systems, especially in terms of data security and fair use, is crucial. Any failure in the system can lead to public distrust.

Implementing modern tax collection methodologies requires balancing the benefits of technological advancement with the challenges of integration, cost, and adaptation. Successful implementation involves careful planning, adequate resource allocation, and continuous evaluation and adaptation of strategies. Collaboration between government entities, technology providers, taxpayers, and other stakeholders is essential to address these challenges effectively. While the challenges are significant, the long-term benefits of improved efficiency, higher compliance, and better taxpayer services justify the efforts and investments in modernizing tax collection systems. Understanding and addressing these challenges is critical for tax authorities to successfully transition to more efficient, transparent, and robust tax collection methodologies (table 4).

Table 4. *Challenges in Implementing Modern Tax Collection Methodologies*

Challenge	Description	Affected Regions	Proposed Solutions
Data Privacy	Concerns about taxpayer data security	Global	Enhanced encryption, secure data protocols
Cost	High initial investment in technology	Developing countries	Phased implementation, international aid
Resistance to Change	Institutional inertia	Global, especially in countries with older systems	Training, gradual integration

Our analysis indicates a significant increase in tax compliance rates with the adoption of modern assessment methods, particularly those integrating digital platforms and data analytics. Traditional methods, while still prevalent in certain regions, show notable efficiency gaps, especially in handling complex tax codes and large taxpayer bases. The implementation of AI and machine learning in tax collection has resulted in improved accuracy and speed in identifying tax evasion and under-reporting. Preliminary data suggests that blockchain technology has the potential to significantly enhance transparency and reduce fraud in tax collection processes.

Conclusion

The analysis of various methodologies for assessing tax collection underscores a significant global trend towards the integration of advanced technologies in tax administration. The shift from traditional to modern methods highlights not only a technological evolution but also a response to the growing complexities of global financial systems. Modern methods, characterized by their efficiency, accuracy, and ability to enhance compliance, are increasingly becoming the norm in developed economies and, gradually, in developing ones.

However, the journey towards modernization is not without its challenges. Issues

such as data privacy, the cost of technological infrastructure, and resistance to change, particularly in regions with deeply ingrained traditional systems, must be addressed thoughtfully. Policymakers and tax authorities are encouraged to adopt a balanced and phased approach, considering the unique economic and administrative contexts of their regions. These suggestions are aimed at facilitating a smoother transition and maximizing the benefits of modern tax systems:

1. Strategic Planning and Phased Implementation

Create a detailed roadmap for transitioning to modern methodologies, including timelines, resource allocation, and risk management strategies.

Instead of a complete overhaul, introduce changes in phases. Start with less complex systems and gradually move to more sophisticated ones, allowing time for adjustment and learning.

2. Investment in Infrastructure and Technology

Explore various funding options, including government allocations, international aid, and public-private partnerships, to invest in necessary technology and infrastructure.

Choose technologies that are well-suited to the region's specific needs and constraints. Avoid overly complex solutions where simpler ones can be effective.

3. Focus on Data Security and Privacy

Ensure strong cybersecurity protocols are in place to protect sensitive tax data. Develop clear policies regarding data use, storage, and privacy, and communicate these policies to the public to build trust.

In conclusion, the future of tax collection lies in the effective adoption of technology-driven methodologies. This transition, while challenging, is essential for the creation of more efficient, transparent, and compliant tax systems globally. As such, ongoing research, policy adaptation, and international cooperation will be key in navigating the complexities of this evolving landscape.

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